

May 31, 2002

TO: SAO/Bob Rasche

From: Timo Saha

SUBJECT: Off-axis data and effective area data for new CSX/SXT designs

This memo documents the off-axis resolution and on-axis effective area for the new CSX/SXT telescope designs.

In my previous memo (dated: May 31, 2002 and titled: CSX/STX telescope design data for 200 mm and 300 mm long mirrors) I used density value of 18.85 gm/cm^2 for the gold coated shells of the designs. More realistic value is 16.965 gm/cm^2 . I believe this value was used in the SAO 70 shell and 85 shell designs to calculate the telescope effective area. Figure 1 plots the effective area for the 230-shell design (mirror length 200 mm) and 167-shell design (mirror length 300 mm). In table 1 the effective area values are listed for both designs. Also listed are the effective areas of outermost shells and innermost shells for both telescopes. The mirror diameter of 800 mm is the dividing value. In case of 200-mm design, there are 109 shells that have diameters larger than 800 mm and 121 shell have diameters smaller than 800 mm. The 300-mm design has 77 shells outside of this diameter and 90 shells inside of this diameter.

Figure 2 plots the off-axis HPD up to half-field angle of 5 arcminutes for the innermost and outermost shells of the telescopes. The HPD values were calculated at 1.25 KeV. The resolution remains roughly constant as a function of energy if the field angles are small compared to the angle of incidence. The adjacent shell inside of the outermost shell starts obstructing the light paths when the half-field angle is larger than 1.25 arcminutes. This obscuration is not taken into account in the calculations. The HPD values are also listed in Table 2.

In Figure 3 the vignetting is plotted as a function of half-field angle for the outermost and innermost shells of the telescopes. The curve is normalized using the on-axis area. The numerical values are listed in Table 3.

Timo Saha

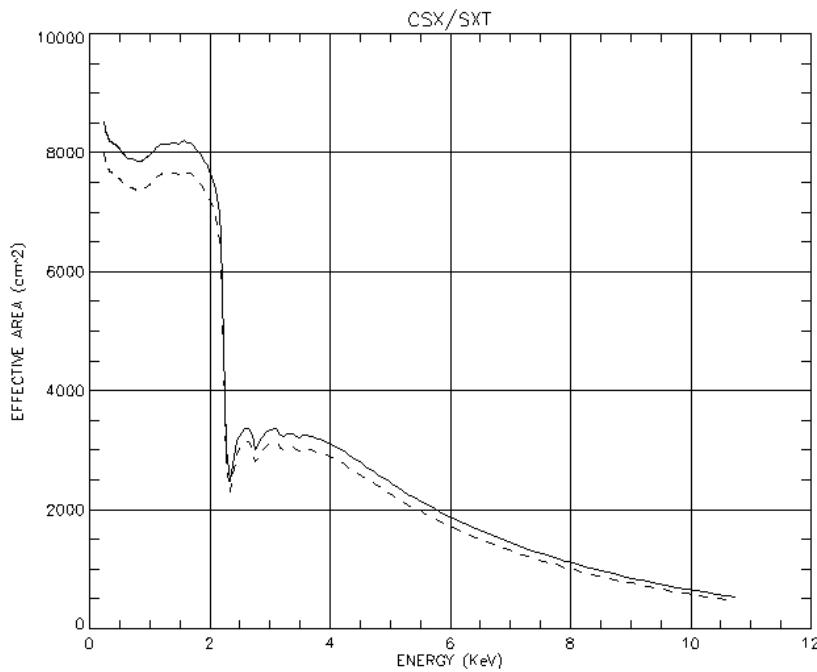


Figure 1. Effective areas of the CSX/SXT telescope designs. The solid line is for the design with 300 mm mirror length and dashed line is for the design with 200 mm mirror lengths. Gold coated surfaces are assumed. The area loss due to structures within the aperture is assumed to be 25%.

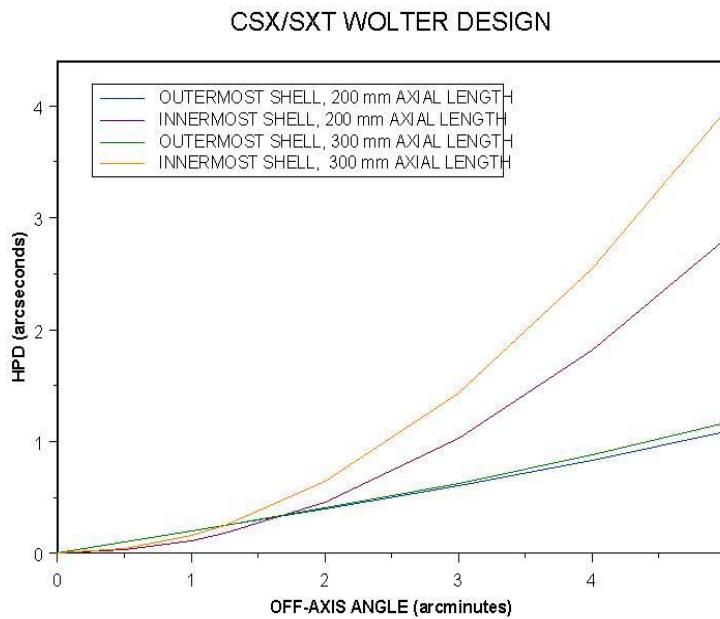


Figure 2. Off-axis resolution of innermost and outermost shells.

CSX/SXT WOLTER DESIGN

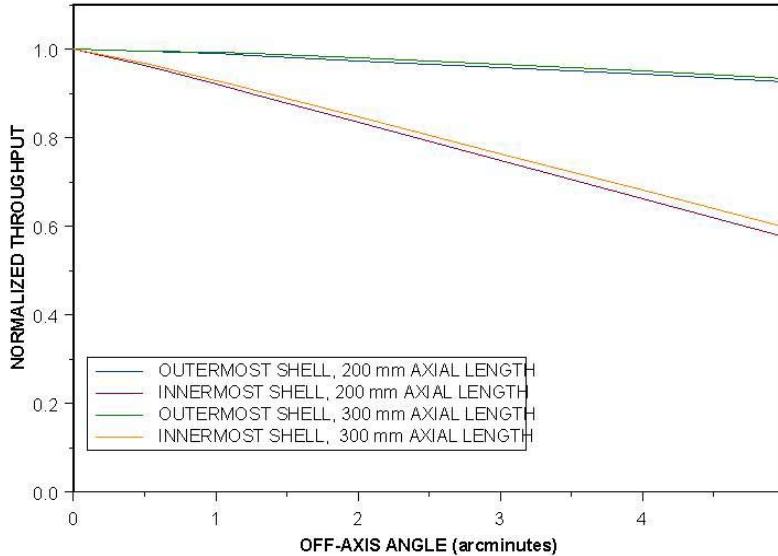


Figure 3. Off-axis throughput of the innermost and outermost shells.

Table 1. Effective areas of the SXT designs.

Energy (KeV)	Coating Gold (LBL optical constants), density 16.965 gm/cm ²					
	Aperture obscuration=0.75		Mirror axial length =300 mm Mirror axial length = 200 mm			
	Effective area total	Effective area of outer shells	Effective area of inner shells	Effective area total	Effective area of outer shells	Effective area of inner shells
0.248	8477.6	6546.9	1754.5	7952.7	6198.2	1754.5
0.252	8451.4	6523.9	1751.5	7928.0	6176.4	1751.5
0.256	8428.9	6504.2	1749.0	7906.8	6157.8	1749.0
0.260	8404.6	6482.9	1746.3	7883.9	6137.6	1746.3
0.264	8381.5	6462.6	1743.7	7862.1	6118.4	1743.7
0.268	8361.2	6444.8	1741.4	7843.0	6101.6	1741.4
0.273	8346.8	6432.3	1739.7	7829.5	6089.7	1739.7
0.277	8342.7	6428.7	1739.3	7825.6	6086.3	1739.3
0.281	8333.4	6420.5	1738.2	7816.8	6078.5	1738.2
0.286	8318.9	6407.7	1736.6	7803.1	6066.5	1736.6
0.291	8303.3	6394.1	1734.9	7788.5	6053.6	1734.9
0.295	8287.6	6380.4	1733.1	7773.7	6040.6	1733.1
0.300	8272.4	6367.0	1731.4	7759.3	6027.9	1731.4
0.305	8258.4	6354.7	1729.8	7746.1	6016.3	1729.8

0.310	8247.7	6345.3	1728.6	7736.0	6007.4	1728.6
0.315	8239.4	6338.1	1727.7	7728.3	6000.6	1727.7
0.320	8229.2	6329.2	1726.5	7718.6	5992.1	1726.5
0.325	8217.6	6318.9	1725.2	7707.7	5982.5	1725.2
0.330	8206.1	6308.9	1723.9	7696.9	5972.9	1723.9
0.336	8195.3	6299.5	1722.7	7686.7	5964.0	1722.7
0.341	8186.1	6291.3	1721.7	7678.0	5956.3	1721.7
0.347	8179.4	6285.5	1720.9	7671.7	5950.8	1720.9
0.352	8180.3	6286.2	1721.0	7672.5	5951.5	1721.0
0.358	8182.0	6287.7	1721.3	7674.1	5952.8	1721.3
0.364	8179.0	6285.1	1721.0	7671.4	5950.4	1721.0
0.370	8173.4	6280.1	1720.3	7666.0	5945.7	1720.3
0.376	8166.6	6274.2	1719.6	7659.7	5940.1	1719.6
0.382	8159.5	6267.9	1718.8	7653.0	5934.2	1718.8
0.388	8152.6	6261.9	1718.0	7646.5	5928.4	1718.0
0.394	8146.7	6256.6	1717.4	7640.9	5923.5	1717.4
0.401	8144.1	6254.3	1717.1	7638.4	5921.3	1717.1
0.407	8146.0	6255.9	1717.4	7640.2	5922.8	1717.4
0.414	8144.8	6254.9	1717.3	7639.1	5921.8	1717.3
0.420	8140.0	6250.6	1716.8	7634.5	5917.8	1716.8
0.427	8133.8	6245.2	1716.1	7628.8	5912.6	1716.1
0.434	8126.9	6239.1	1715.4	7622.2	5906.9	1715.4
0.441	8119.6	6232.6	1714.6	7615.3	5900.8	1714.6
0.448	8113.3	6227.1	1713.9	7609.4	5895.5	1713.9
0.455	8109.0	6223.3	1713.4	7605.4	5891.9	1713.4
0.463	8103.1	6218.1	1712.8	7599.8	5887.0	1712.8
0.470	8095.3	6211.2	1712.0	7592.5	5880.5	1712.0
0.478	8086.5	6203.4	1711.0	7584.1	5873.1	1711.0
0.486	8076.8	6194.9	1709.9	7575.0	5865.1	1709.9
0.493	8066.6	6185.9	1708.8	7565.4	5856.6	1708.8
0.501	8056.0	6176.6	1707.6	7555.4	5847.8	1707.6
0.510	8045.5	6167.3	1706.5	7545.5	5839.0	1706.5
0.518	8035.1	6158.2	1705.4	7535.7	5830.3	1705.4
0.526	8024.1	6148.5	1704.1	7525.3	5821.2	1704.1
0.535	8012.7	6138.5	1702.9	7514.6	5811.7	1702.9
0.543	8001.2	6128.4	1701.6	7503.7	5802.1	1701.6
0.552	7989.5	6118.1	1700.4	7492.8	5792.4	1700.4
0.561	7978.1	6108.1	1699.1	7482.0	5782.9	1699.1
0.570	7967.8	6099.0	1698.0	7472.3	5774.3	1698.0
0.579	7957.7	6090.1	1696.9	7462.8	5765.9	1696.9
0.589	7947.1	6080.8	1695.7	7452.8	5757.1	1695.7
0.598	7936.6	6071.5	1694.6	7442.8	5748.3	1694.6
0.608	7926.2	6062.3	1693.5	7433.1	5739.6	1693.5
0.618	7916.3	6053.6	1692.4	7423.8	5731.4	1692.4
0.628	7907.2	6045.6	1691.4	7415.2	5723.8	1691.4
0.638	7899.6	6038.8	1690.6	7408.0	5717.4	1690.6

0.648	7895.3	6035.1	1690.2	7404.0	5713.8	1690.2
0.659	7900.3	6039.3	1690.9	7408.7	5717.8	1690.9
0.669	7905.0	6043.3	1691.5	7413.1	5721.6	1691.5
0.680	7904.8	6043.0	1691.6	7412.9	5721.3	1691.6
0.691	7902.8	6041.1	1691.5	7411.0	5719.6	1691.5
0.702	7899.6	6038.2	1691.2	7408.0	5716.8	1691.2
0.714	7895.4	6034.5	1690.9	7404.1	5713.2	1690.9
0.725	7890.1	6029.6	1690.4	7399.0	5708.7	1690.4
0.737	7883.7	6023.9	1689.7	7393.0	5703.3	1689.7
0.749	7877.5	6018.4	1689.1	7387.2	5698.0	1689.1
0.761	7871.5	6013.0	1688.6	7381.5	5692.9	1688.6
0.773	7865.7	6007.8	1688.0	7376.1	5688.1	1688.0
0.786	7860.5	6003.1	1687.6	7371.2	5683.6	1687.6
0.799	7858.8	6001.5	1687.5	7369.5	5682.0	1687.5
0.811	7861.3	6003.5	1687.9	7371.9	5684.0	1687.9
0.825	7861.5	6003.5	1688.1	7372.1	5684.0	1688.1
0.838	7861.2	6003.1	1688.2	7371.8	5683.6	1688.2
0.852	7861.1	6002.8	1688.4	7371.7	5683.3	1688.4
0.865	7861.4	6002.9	1688.6	7372.0	5683.4	1688.6
0.879	7868.6	6009.0	1689.6	7378.8	5689.2	1689.6
0.893	7884.1	6022.3	1691.5	7393.4	5701.8	1691.5
0.908	7894.3	6031.1	1692.9	7403.0	5710.1	1692.9
0.923	7902.9	6038.4	1694.1	7411.1	5717.0	1694.1
0.938	7910.8	6045.0	1695.2	7418.5	5723.3	1695.2
0.953	7919.2	6052.1	1696.4	7426.4	5730.0	1696.4
0.968	7931.4	6062.6	1698.0	7437.9	5739.9	1698.0
0.984	7943.7	6073.1	1699.6	7449.5	5749.9	1699.6
1.000	7954.4	6082.2	1701.1	7459.6	5758.5	1701.1
1.016	7964.9	6091.1	1702.5	7469.5	5766.9	1702.5
1.032	7979.7	6103.7	1704.5	7483.4	5778.9	1704.5
1.049	8006.1	6126.6	1707.8	7508.3	5800.6	1707.8
1.066	8032.2	6149.1	1711.0	7532.9	5821.9	1711.0
1.083	8054.1	6168.0	1713.8	7553.5	5839.7	1713.8
1.101	8073.3	6184.4	1716.3	7571.6	5855.3	1716.3
1.119	8090.3	6199.0	1718.5	7587.6	5869.1	1718.5
1.137	8105.6	6212.0	1720.6	7602.0	5881.4	1720.6
1.155	8119.2	6223.6	1722.4	7614.8	5892.4	1722.4
1.174	8131.2	6233.7	1724.2	7626.1	5902.0	1724.2
1.193	8141.6	6242.5	1725.7	7636.0	5910.3	1725.7
1.212	8149.9	6249.3	1727.0	7643.8	5916.7	1727.0
1.232	8152.5	6251.2	1727.7	7646.2	5918.5	1727.7
1.251	8148.4	6247.0	1727.7	7642.3	5914.6	1727.7
1.272	8145.5	6244.1	1727.8	7639.6	5911.9	1727.8
1.292	8143.4	6241.7	1728.0	7637.6	5909.6	1728.0
1.313	8142.9	6240.8	1728.3	7637.2	5908.8	1728.3
1.334	8150.3	6246.8	1729.6	7644.1	5914.5	1729.6

1.356	8156.9	6252.0	1730.9	7650.3	5919.4	1730.9
1.378	8161.2	6255.2	1731.9	7654.3	5922.5	1731.9
1.400	8164.2	6257.2	1732.8	7657.1	5924.4	1732.8
1.423	8163.7	6256.2	1733.3	7656.7	5923.4	1733.3
1.446	8153.9	6246.9	1732.8	7647.4	5914.6	1732.8
1.469	8145.8	6239.2	1732.5	7639.8	5907.3	1732.5
1.493	8144.2	6237.1	1732.9	7638.2	5905.3	1732.9
1.517	8174.1	6262.6	1736.9	7666.4	5929.5	1736.9
1.542	8195.5	6280.6	1740.0	7686.6	5946.6	1740.0
1.567	8201.2	6284.8	1741.4	7692.0	5950.6	1741.4
1.592	8186.9	6271.3	1740.6	7678.5	5937.8	1740.6
1.618	8173.4	6258.5	1740.0	7665.8	5925.8	1740.0
1.644	8162.4	6247.9	1739.7	7655.4	5915.8	1739.7
1.671	8161.4	6246.0	1740.5	7654.5	5913.9	1740.5
1.698	8145.3	6230.6	1739.8	7639.3	5899.5	1739.8
1.725	8117.9	6205.3	1737.9	7613.4	5875.5	1737.9
1.753	8098.5	6187.0	1736.9	7595.1	5858.2	1736.9
1.781	8054.5	6146.9	1733.3	7553.7	5820.3	1733.3
1.810	8004.0	6101.1	1729.1	7506.1	5777.0	1729.1
1.839	7977.9	6076.5	1727.7	7481.4	5753.8	1727.7
1.869	7930.2	6032.9	1724.0	7436.6	5712.5	1724.0
1.899	7868.2	5976.4	1718.9	7378.1	5659.2	1718.9
1.930	7826.5	5937.8	1716.1	7338.8	5622.7	1716.1
1.961	7782.4	5896.7	1713.3	7297.2	5583.9	1713.3
1.993	7708.0	5828.7	1707.5	7227.1	5519.6	1707.5
2.025	7617.9	5746.6	1700.2	7142.2	5442.0	1700.2
2.058	7519.2	5656.5	1692.3	7049.2	5356.8	1692.3
2.091	7396.8	5544.9	1682.5	6933.8	5251.4	1682.5
2.125	7233.5	5396.5	1668.9	6780.0	5111.1	1668.9
2.159	6991.4	5177.4	1648.0	6551.9	4904.0	1648.0
2.194	6599.5	4823.9	1612.9	6182.6	4569.8	1612.9
2.230	4766.7	3226.5	1398.1	4455.4	3057.3	1398.1
2.266	3014.1	1822.9	1079.8	2806.3	1726.5	1079.8
2.303	2844.1	1690.3	1045.8	2646.6	1600.8	1045.8
2.340	2473.9	1425.6	949.7	2299.6	1349.9	949.7
2.378	2772.2	1658.5	1009.3	2579.8	1570.6	1009.3
2.416	3005.2	1840.8	1055.4	2798.8	1743.3	1055.4
2.455	3135.4	1941.5	1082.3	2921.1	1838.8	1082.3
2.495	3221.8	2008.1	1100.4	3002.3	1901.8	1100.4
2.535	3301.0	2068.6	1117.4	3076.6	1959.2	1117.4
2.576	3364.1	2115.7	1132.0	3135.9	2003.9	1132.0
2.618	3367.4	2114.3	1136.2	3138.8	2002.6	1136.2
2.660	3345.1	2093.7	1134.8	3117.8	1983.1	1134.8
2.703	3257.5	2018.2	1123.7	3035.3	1911.6	1123.7
2.747	3014.8	1827.5	1076.3	2807.1	1730.8	1076.3
2.791	3067.5	1869.4	1086.1	2856.6	1770.5	1086.1

2.837	3189.5	1962.9	1112.0	2971.2	1859.2	1112.0
2.882	3236.8	1996.9	1124.2	3015.6	1891.4	1124.2
2.929	3287.1	2033.0	1137.1	3062.8	1925.7	1137.1
2.976	3328.7	2061.4	1149.2	3101.8	1952.6	1149.2
3.025	3348.0	2071.6	1157.5	3119.8	1962.3	1157.5
3.074	3355.4	2072.0	1163.8	3126.6	1962.8	1163.8
3.123	3336.5	2050.4	1166.3	3108.7	1942.4	1166.3
3.174	3256.0	1982.0	1155.3	3032.8	1877.5	1155.3
3.225	3235.8	1962.2	1154.9	3013.7	1858.8	1154.9
3.277	3274.3	1986.8	1167.6	3049.7	1882.2	1167.6
3.330	3285.2	1988.8	1175.6	3059.7	1884.1	1175.6
3.384	3273.7	1972.2	1180.3	3048.7	1868.4	1180.3
3.439	3224.0	1925.9	1177.2	3001.7	1824.5	1177.2
3.494	3217.3	1914.8	1181.2	2995.2	1814.0	1181.2
3.551	3257.0	1938.0	1196.2	3032.2	1836.0	1196.2
3.608	3250.0	1923.2	1203.3	3025.3	1822.0	1203.3
3.667	3237.1	1903.5	1209.5	3012.8	1803.3	1209.5
3.726	3219.0	1879.3	1215.1	2995.3	1780.3	1215.1
3.786	3196.7	1851.4	1220.1	2973.9	1753.8	1220.1
3.848	3175.6	1823.9	1226.0	2953.6	1727.5	1226.0
3.910	3149.3	1791.7	1231.3	2928.2	1696.9	1231.3
3.973	3118.3	1755.5	1236.1	2898.5	1662.4	1236.1
4.037	3085.1	1717.2	1240.6	2866.6	1625.9	1240.6
4.103	3051.4	1678.1	1245.6	2834.2	1588.6	1245.6
4.169	3015.6	1637.4	1250.1	2799.8	1549.7	1250.1
4.236	2983.2	1597.3	1257.1	2768.6	1511.5	1257.1
4.305	2912.5	1530.0	1253.9	2701.3	1447.4	1253.9
4.375	2872.9	1485.8	1258.2	2663.3	1405.2	1258.2
4.445	2823.5	1434.1	1260.2	2616.1	1356.0	1260.2
4.517	2777.3	1384.7	1263.1	2572.0	1308.8	1263.1
4.590	2728.1	1333.0	1265.4	2525.0	1259.6	1265.4
4.665	2678.9	1281.3	1267.6	2478.0	1210.4	1267.6
4.740	2628.1	1228.6	1269.4	2429.6	1160.3	1269.4
4.817	2576.1	1175.1	1270.7	2380.1	1109.4	1270.7
4.895	2522.3	1120.6	1271.2	2328.9	1057.6	1271.2
4.974	2468.5	1066.4	1271.6	2277.7	1006.1	1271.6
5.054	2411.4	1010.5	1270.5	2223.6	953.1	1270.5
5.136	2358.7	958.0	1270.3	2173.6	903.3	1270.3
5.219	2307.3	906.1	1270.7	2124.8	854.1	1270.7
5.303	2244.7	849.2	1265.5	2065.7	800.2	1265.5
5.389	2206.3	806.4	1269.4	2029.1	759.7	1269.4
5.476	2155.5	756.2	1268.9	1981.1	712.2	1268.9
5.565	2105.8	707.2	1268.2	1934.1	665.8	1268.2
5.655	2055.6	658.4	1266.8	1886.6	619.8	1266.8
5.746	2004.9	610.1	1264.7	1838.8	574.1	1264.7
5.839	1954.1	562.8	1261.4	1790.9	529.5	1261.4

5.934	1911.9	519.9	1261.9	1751.0	489.1	1261.9
6.030	1859.5	473.3	1256.6	1701.7	445.1	1256.6
6.127	1814.4	430.8	1254.2	1659.3	405.1	1254.2
6.226	1768.4	388.7	1250.6	1616.0	365.4	1250.6
6.327	1722.5	347.6	1246.1	1572.9	326.8	1246.1
6.429	1677.0	307.9	1240.7	1530.2	289.5	1240.7
6.533	1632.0	269.8	1234.3	1488.0	253.6	1234.3
6.639	1587.4	233.4	1226.8	1446.2	219.4	1226.8
6.747	1543.3	198.9	1218.0	1405.0	187.0	1218.0
6.856	1499.8	166.6	1207.6	1364.3	156.7	1207.6
6.967	1456.8	136.9	1195.3	1324.1	128.8	1195.3
7.079	1414.3	110.1	1180.9	1284.5	103.6	1180.9
7.194	1372.5	86.6	1164.0	1245.5	81.5	1164.0
7.310	1331.2	66.8	1144.2	1207.1	62.8	1144.2
7.428	1290.5	50.8	1121.5	1169.2	47.7	1121.5
7.548	1250.4	38.4	1095.9	1132.0	36.1	1095.9
7.671	1211.0	29.1	1068.0	1095.4	27.4	1068.0
7.795	1172.2	22.3	1038.5	1059.4	20.9	1038.5
7.921	1134.0	17.2	1007.9	1024.0	16.1	1007.9
8.049	1096.4	13.4	976.7	989.3	12.6	976.7
8.179	1059.5	10.5	945.3	955.2	9.9	945.3
8.311	1023.3	8.3	913.9	921.7	7.8	913.9
8.446	987.7	6.7	882.6	888.9	6.3	882.6
8.582	952.7	5.4	851.7	856.7	5.0	851.7
8.721	918.4	4.3	821.0	825.1	4.1	821.0
8.862	884.7	3.5	790.8	794.2	3.3	790.8
9.005	851.7	2.9	761.1	763.8	2.7	761.1
9.151	819.2	2.4	731.9	734.1	2.2	731.9
9.299	787.4	1.9	703.1	704.9	1.8	703.1
9.450	756.2	1.6	674.9	676.4	1.5	674.9
9.602	725.6	1.3	647.2	648.4	1.2	647.2
9.758	695.6	1.1	620.0	621.0	1.0	620.0
9.916	666.1	0.9	593.3	594.2	0.9	593.3
10.076	637.2	0.8	567.1	567.8	0.7	567.1

Table 2. Off-axis resolution of the SXT designs.

HFA (arcminutes)	50% encircled energy (arcseconds)			
	sxt_200 outer shell	sxt_200 inner shell	sxt_300 outer shell	sxt_300 inner shell
0.00	0	0	0	0
0.50	0.098	0.029	0.098	0.041
1.00	0.196	0.116	0.197	0.162
1.25	0.245	0.181	0.247	0.253
2.00	0.395	0.457	0.403	0.642
3.00	0.603	1.03	0.626	1.43
4.00	0.835	1.82	0.877	2.55
5.00	1.08	2.81	1.17	3.96

Table 3. Normalized throughput of the SXT designs for half-field angles up to 5 arcminutes.

HFA (arcminutes)	normalized throughput			
	sxt_200 outer shell	sxt_200 inner shell	sxt_300 outer shell	sxt_300 inner shell
0.00	1.000	1.000	1.000	1.000
0.50	0.995	0.964	0.995	0.969
1.00	0.990	0.921	0.992	0.929
1.25	0.986	0.899	0.990	0.909
2.00	0.974	0.834	0.980	0.846
3.00	0.958	0.749	0.965	0.763
4.00	0.943	0.662	0.950	0.681
5.00	0.926	0.576	0.934	0.599